Extending the reach in an HPS-style experiment

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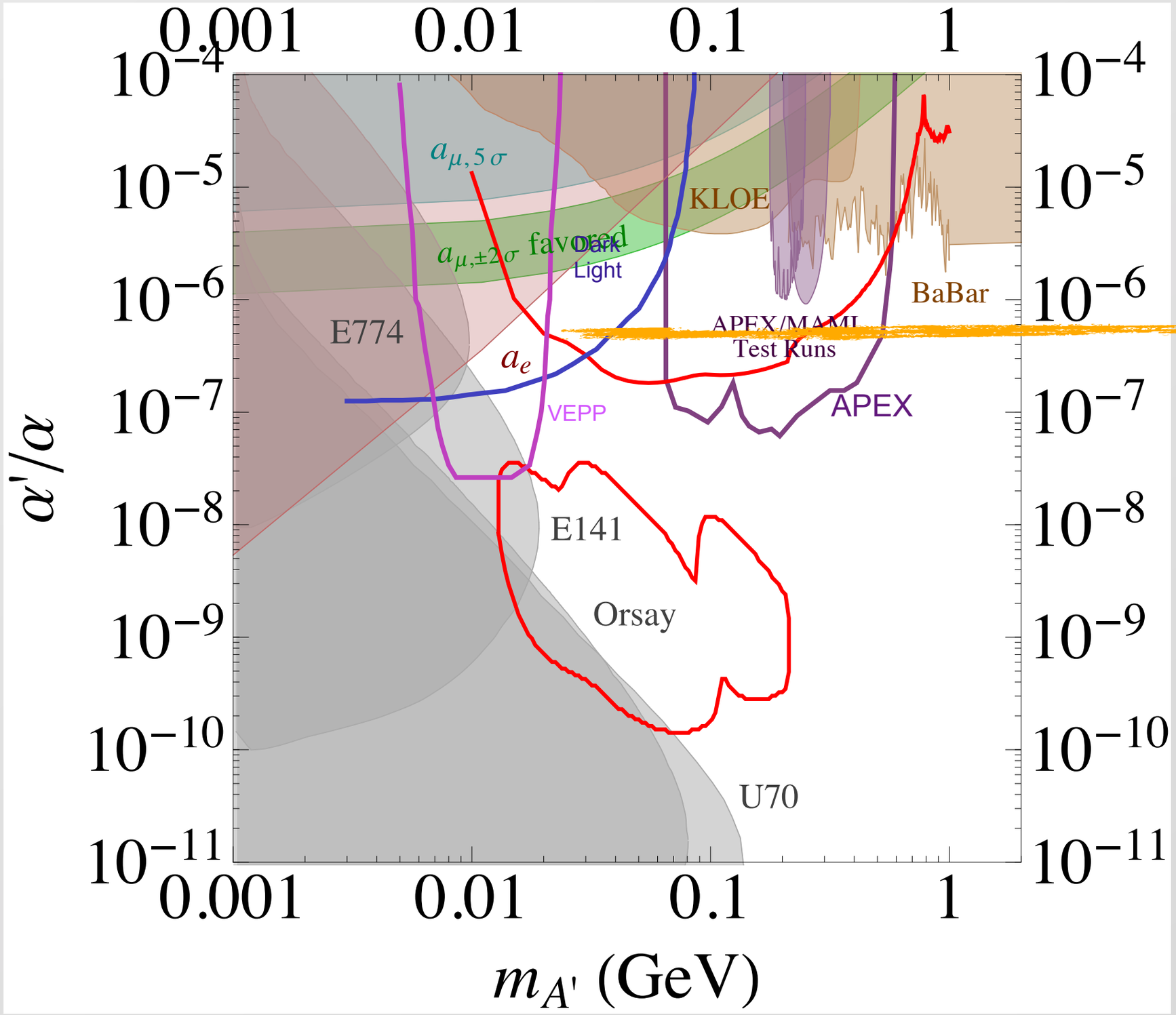
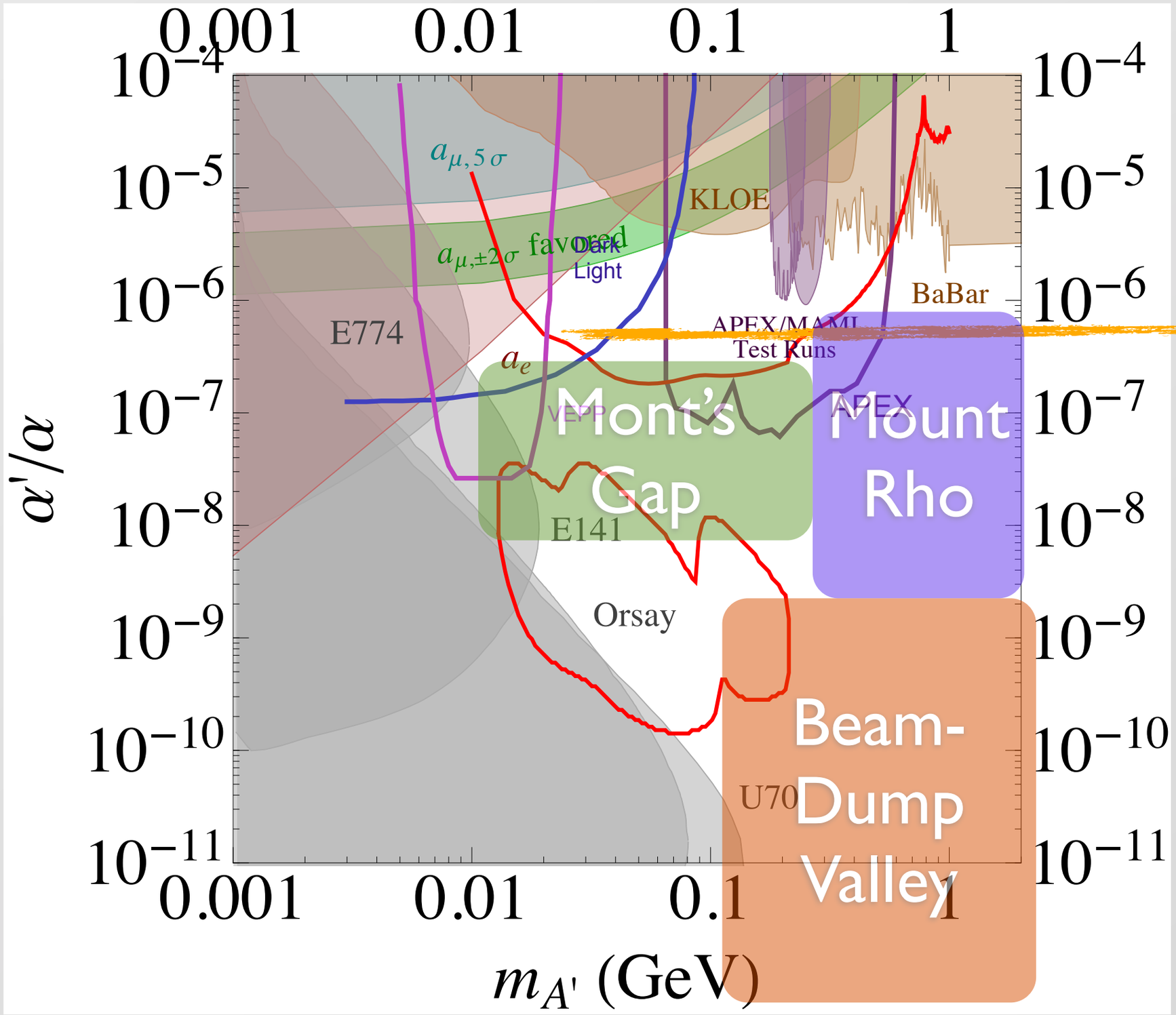
SLAC National Accelerator Laboratory
Snowmass 2013: NLWCP Parallel Session
Wednesday, July 31, 2013

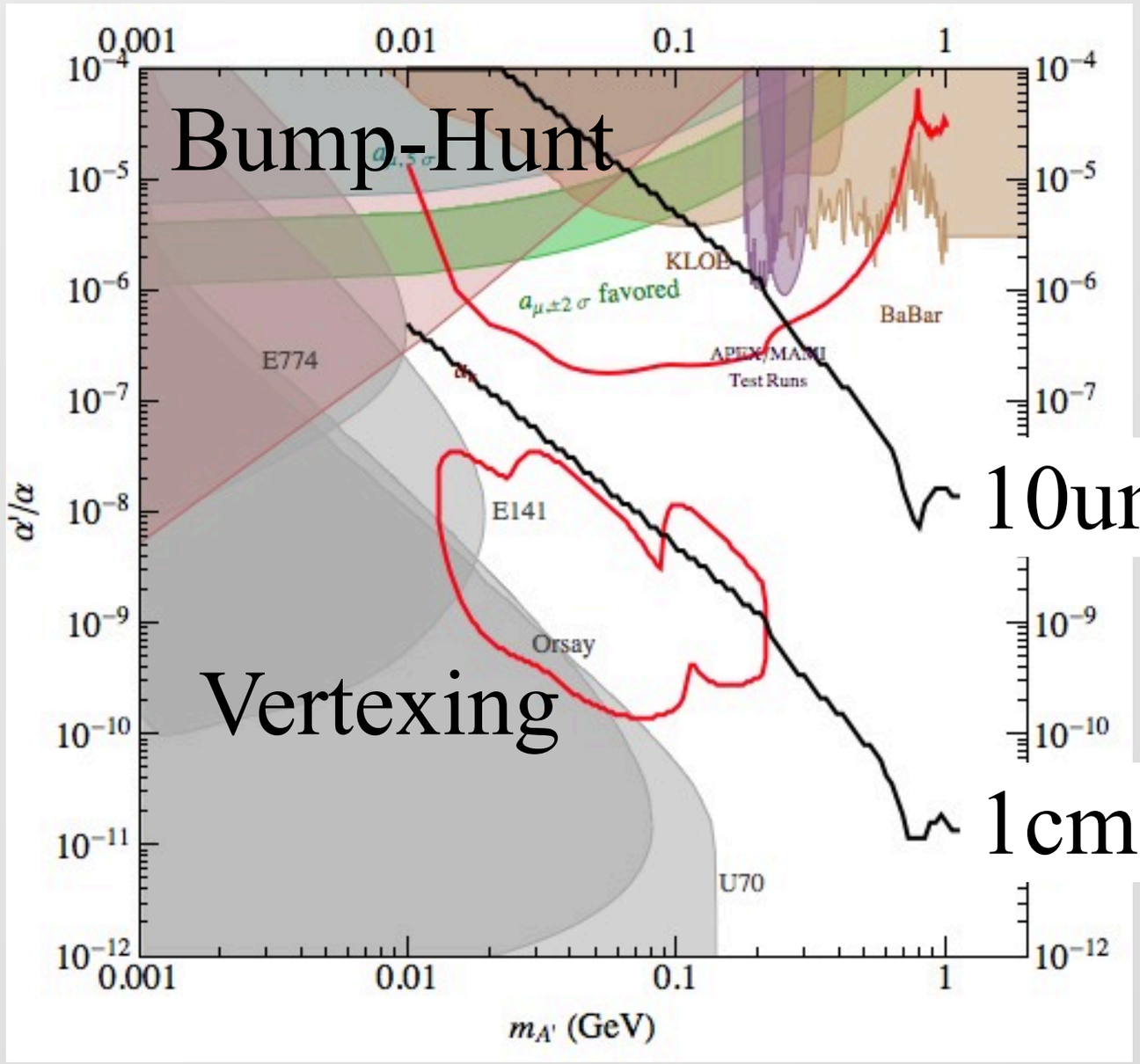
Where we (almost) are



Where we want to go.



I have a heavy HPS bias!



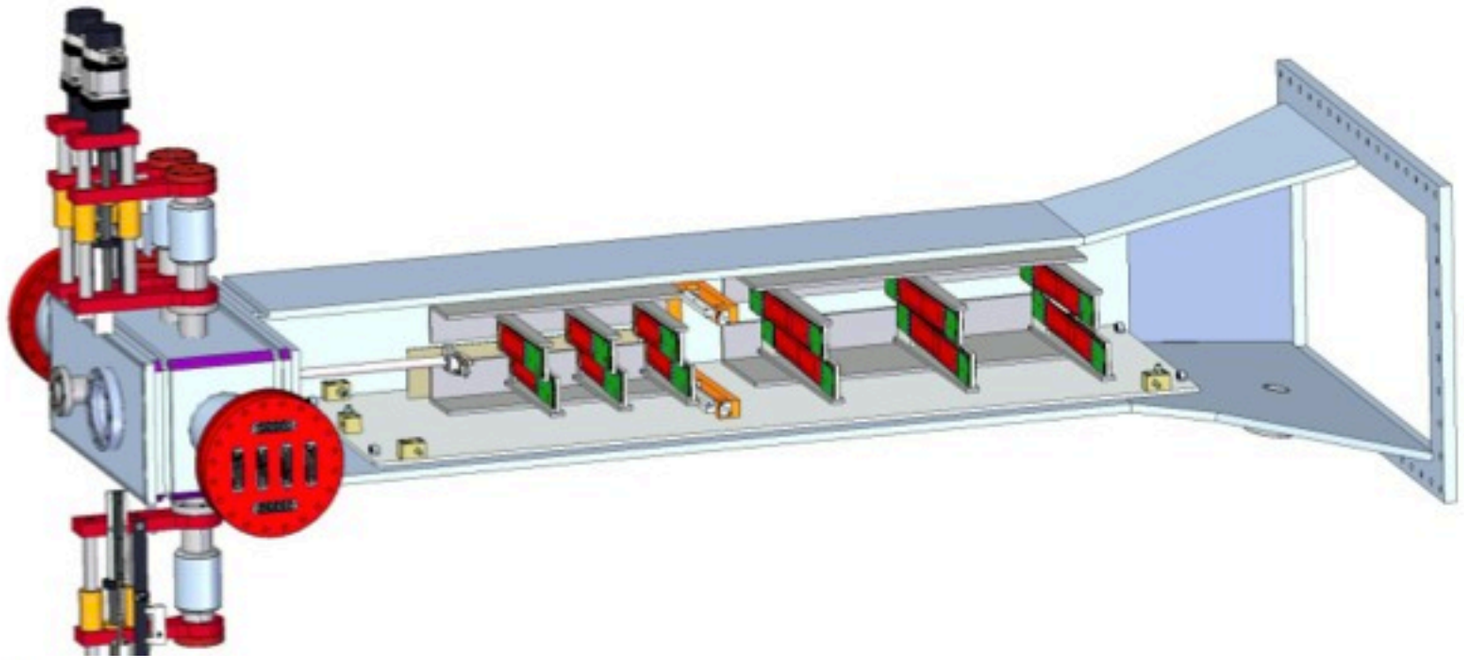
Commissioning Run (dashed):

1 week with 50nA @ 1.1 GeV
1 week with 200nA @ 2.2 GeV

Production Run (solid):

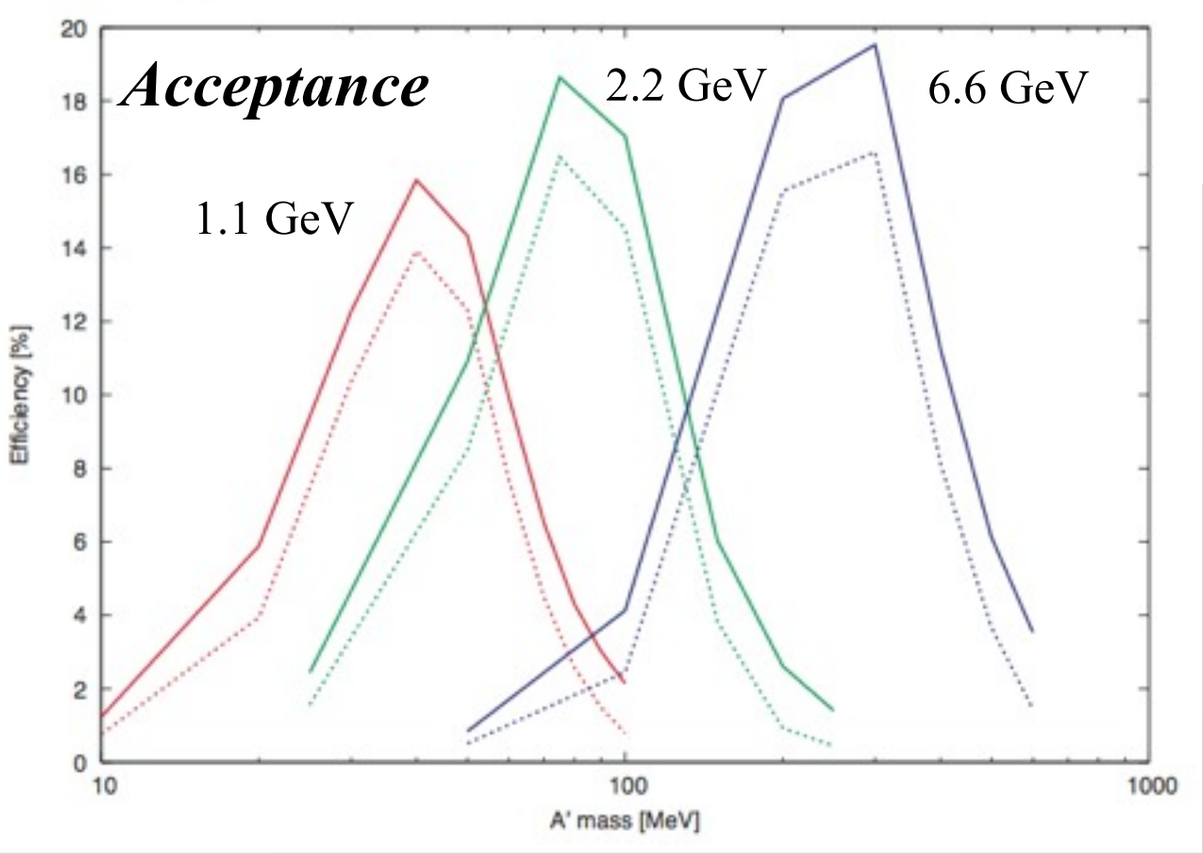
2 weeks with 200nA @ 2.2 GeV
2 weeks with 450nA @ 6.6 GeV

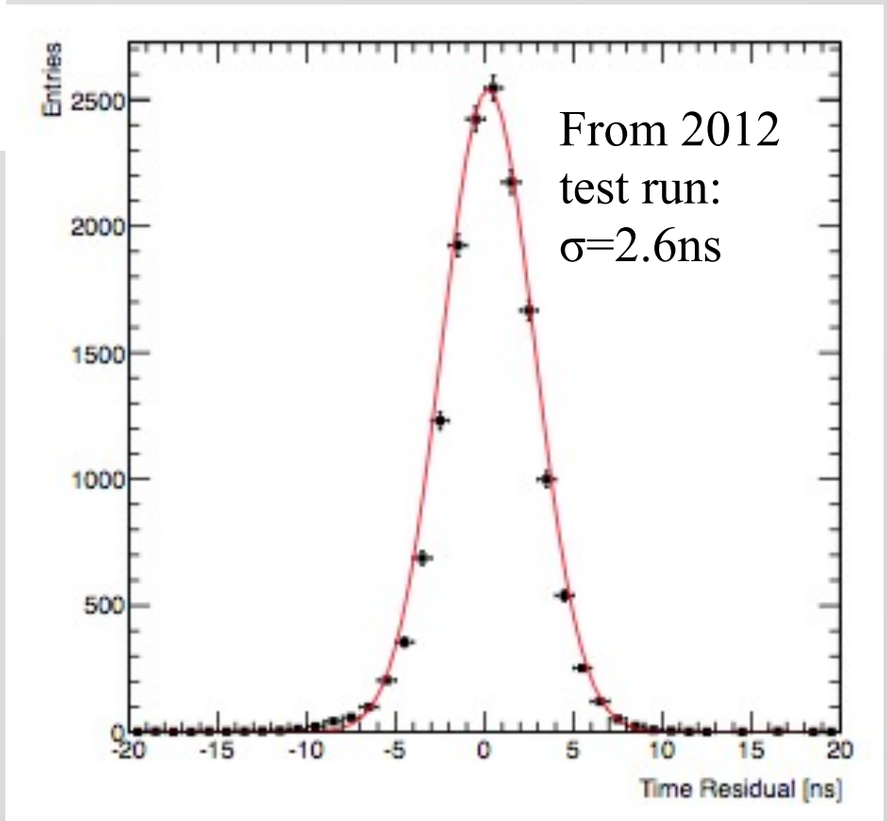
The HPS Detector



SVT:
6 double layers of single-sided Si strips; small angle stereo pairs

$X=0.7/X_0\%$ per double layer





Buttons to push on an HPSish experiment

- Mass resolution
  - Thinner detectors; larger BxL
- Vertex resolution
  - thinner detectors (first few layers), decrease distance from target to L1
- Acceptance
  - bigger detector (high mass); smaller deadzone (low mass)
- Integrated luminosity
  - higher current; thicker target; longer runtime
- Add in muons and pion
  - new detector downstream of tracker, $$
- Lower Z target
  - increase cross-section at mass > 500MeV

There are trade offs here...some just $$$ (muon detector), but some in the reach as well

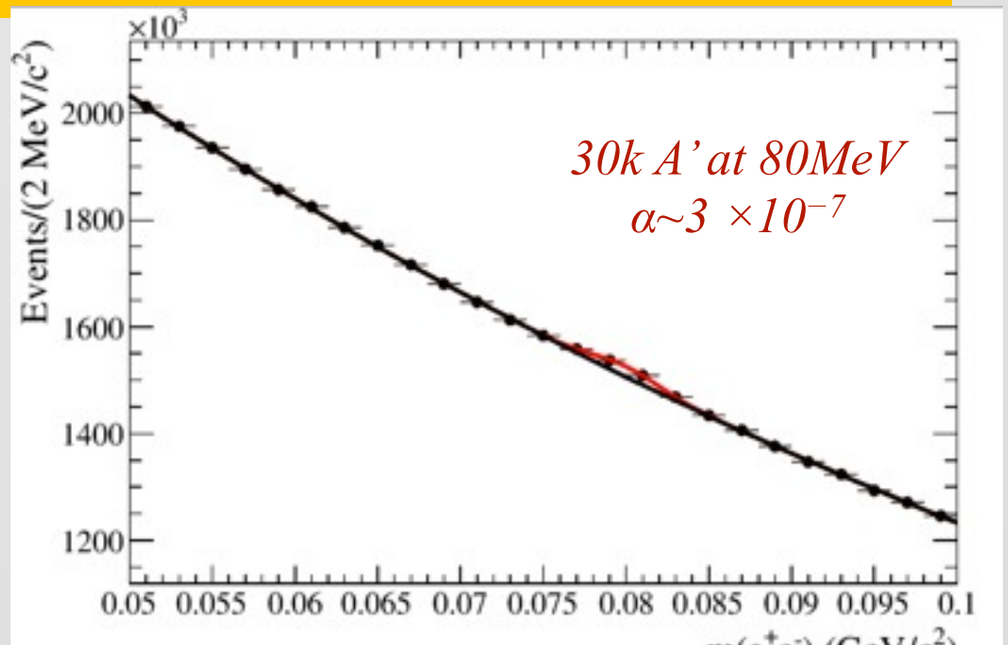
For this talk, I'm assuming that the technical challenges have been conquered (i.e. we have thin, fast pixels);

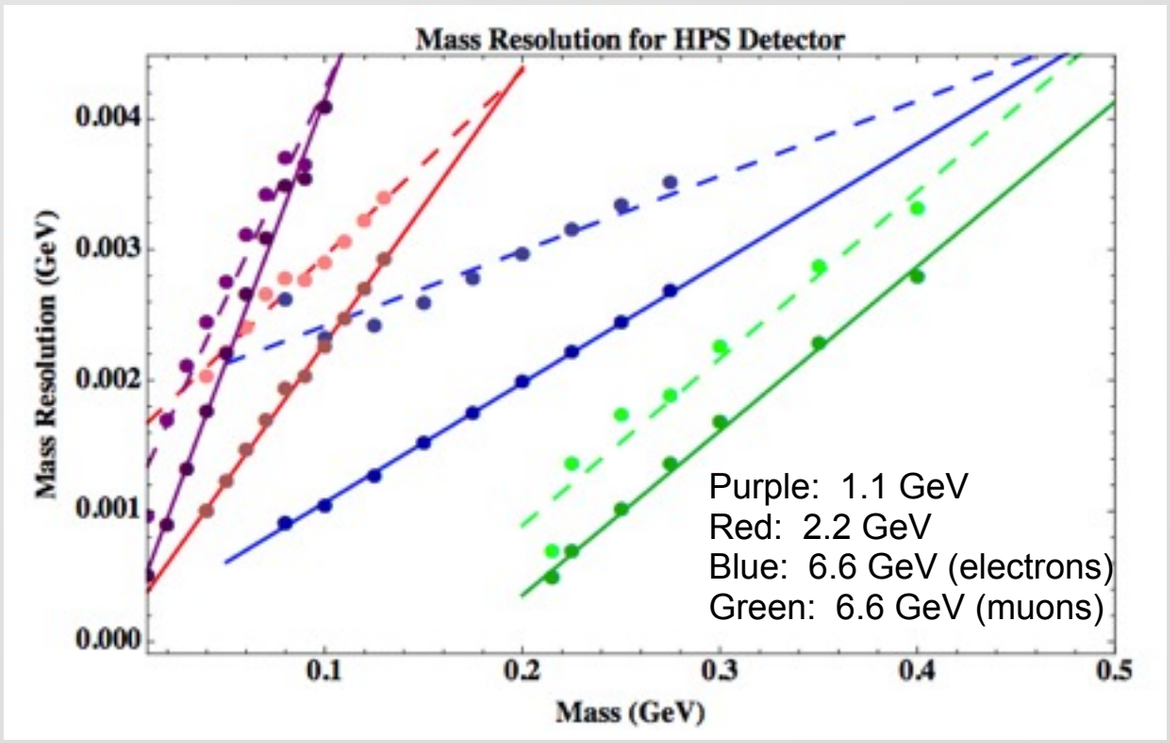
Mass resolution improvements for bump-hunt region

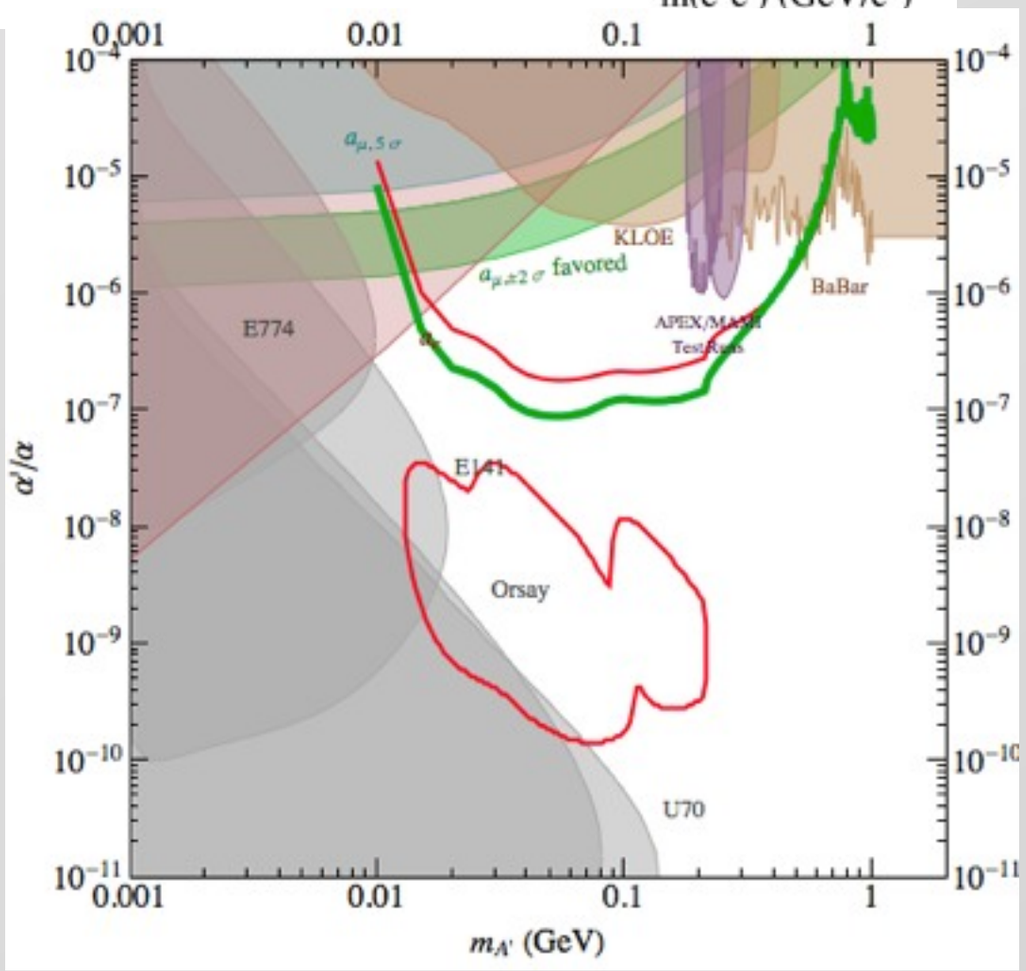
Improving mass resolution effectively reduces the background under the "bump"→reach scales like sqrt(σ)

- momentum resolution→ material throughout whole tracker & ∫L×B
- angular resolution→ material in first few layers

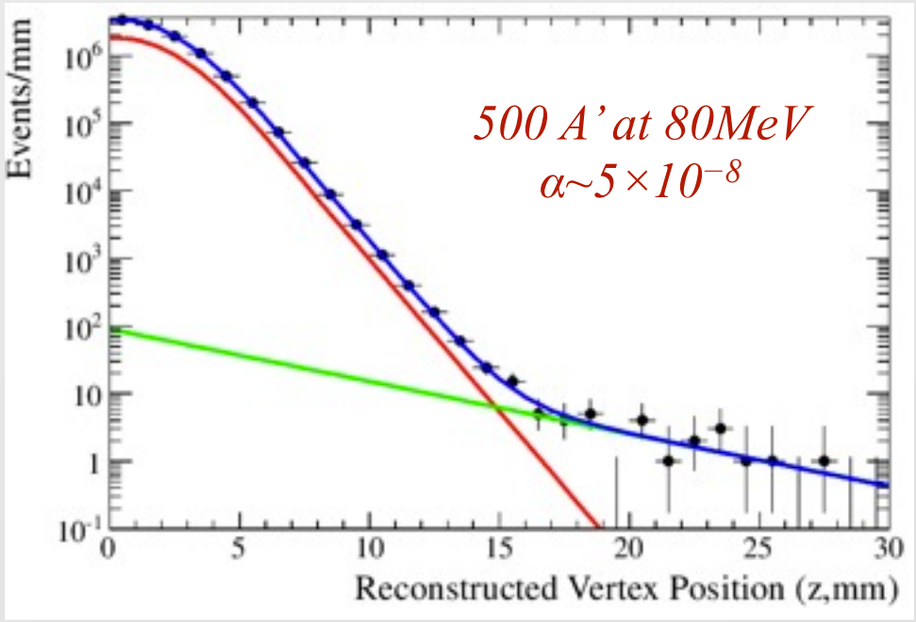
Through some combination of these, I'll say we could potentially achieve an improvement by x4...this may be crazy!





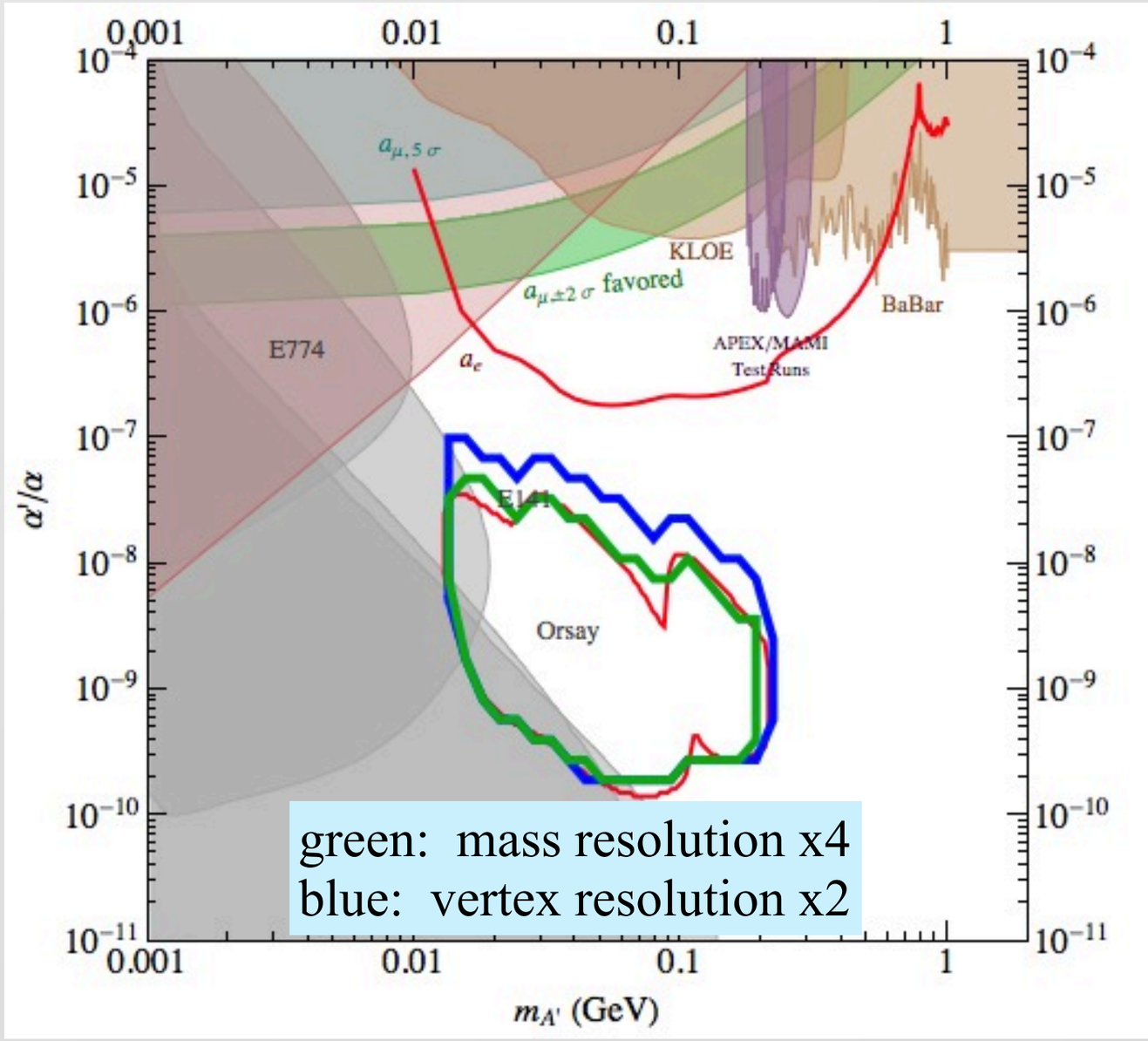


Vertex & Mass resolution in the vertexing region



Vertexing reach region, very different from bump-hunt ... effectively a 0 bkg search.

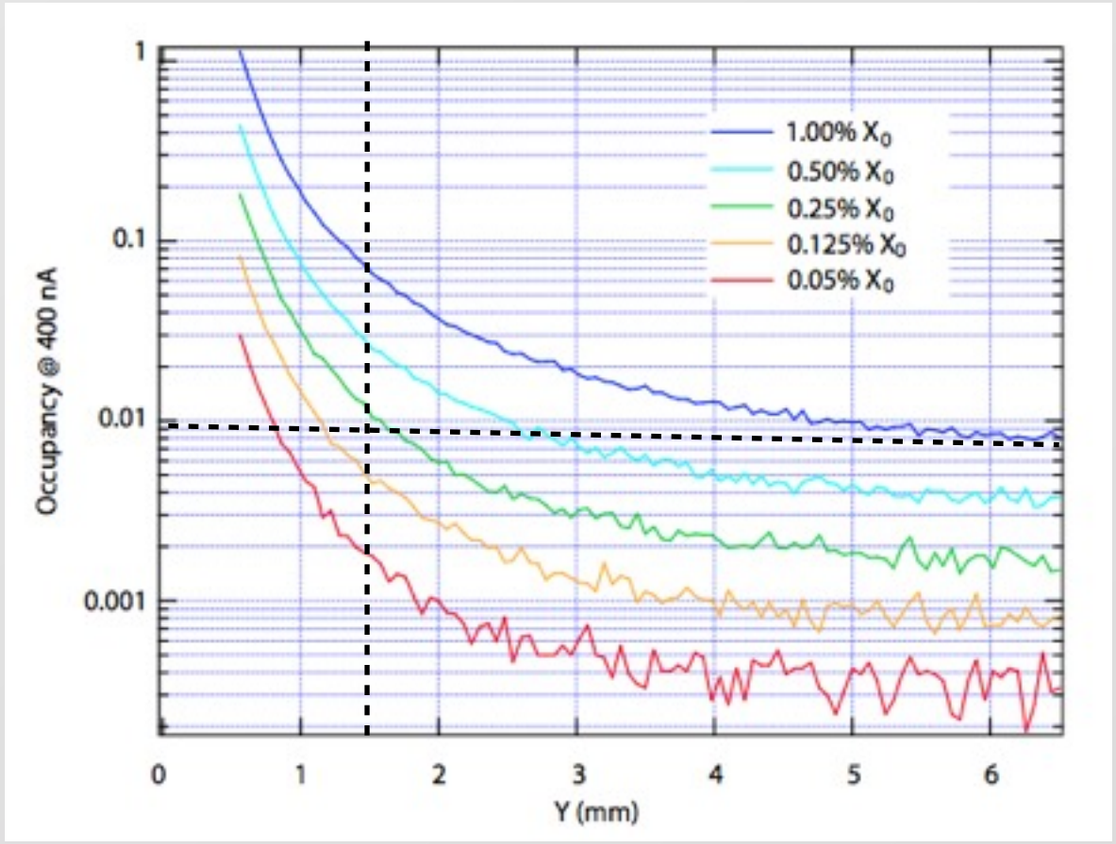
Optimal vertex position cut at the edge of a steep exponential tail.

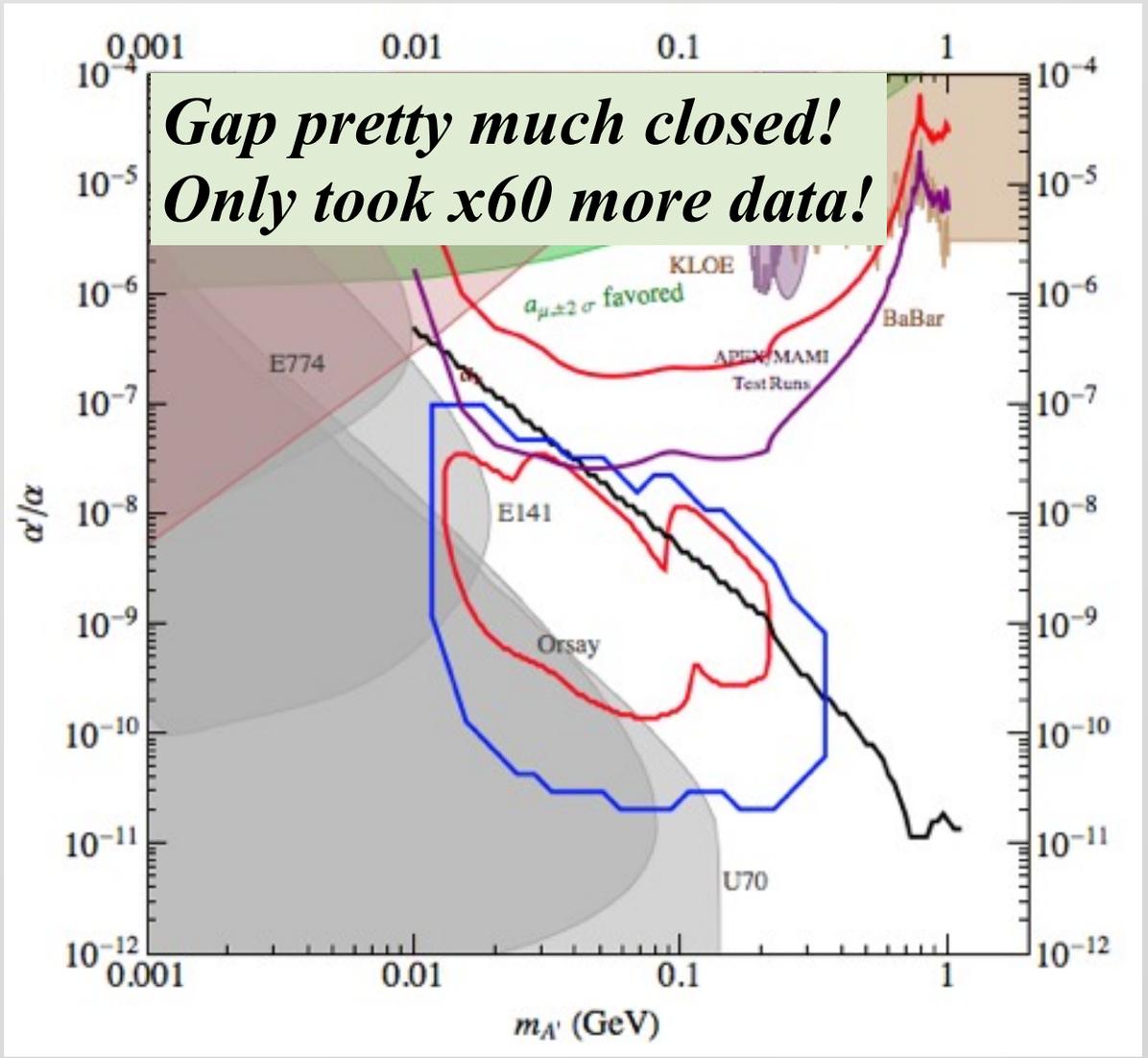


Improving mass resolution → reduces entire bkg distribution → ***very little effect on reach***
Improving vertex resolution → reduces slope of bkg distribution → ***large effect on reach***

Increasing the luminosity

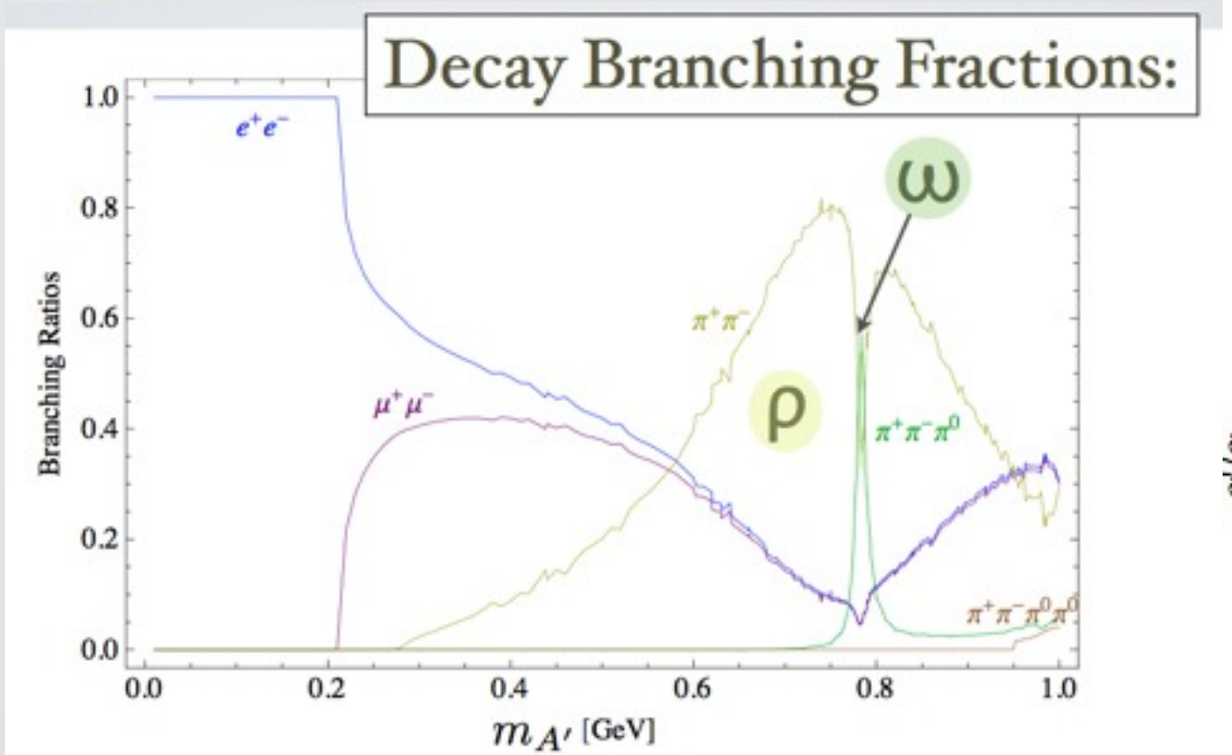
- Three ways to increase the integrated luminosity
  - run longer: take 3 months/energy (roughly 6x beam time now)
  - increase current: up by ~ x5 but with some loss in vertexing efficiency due to higher occupancy in L1; probably need a sophisticated target;
  - increase target thickness: let's say x2; more MS in target→higher occupancy;
- Remember, this is a 10year plan!

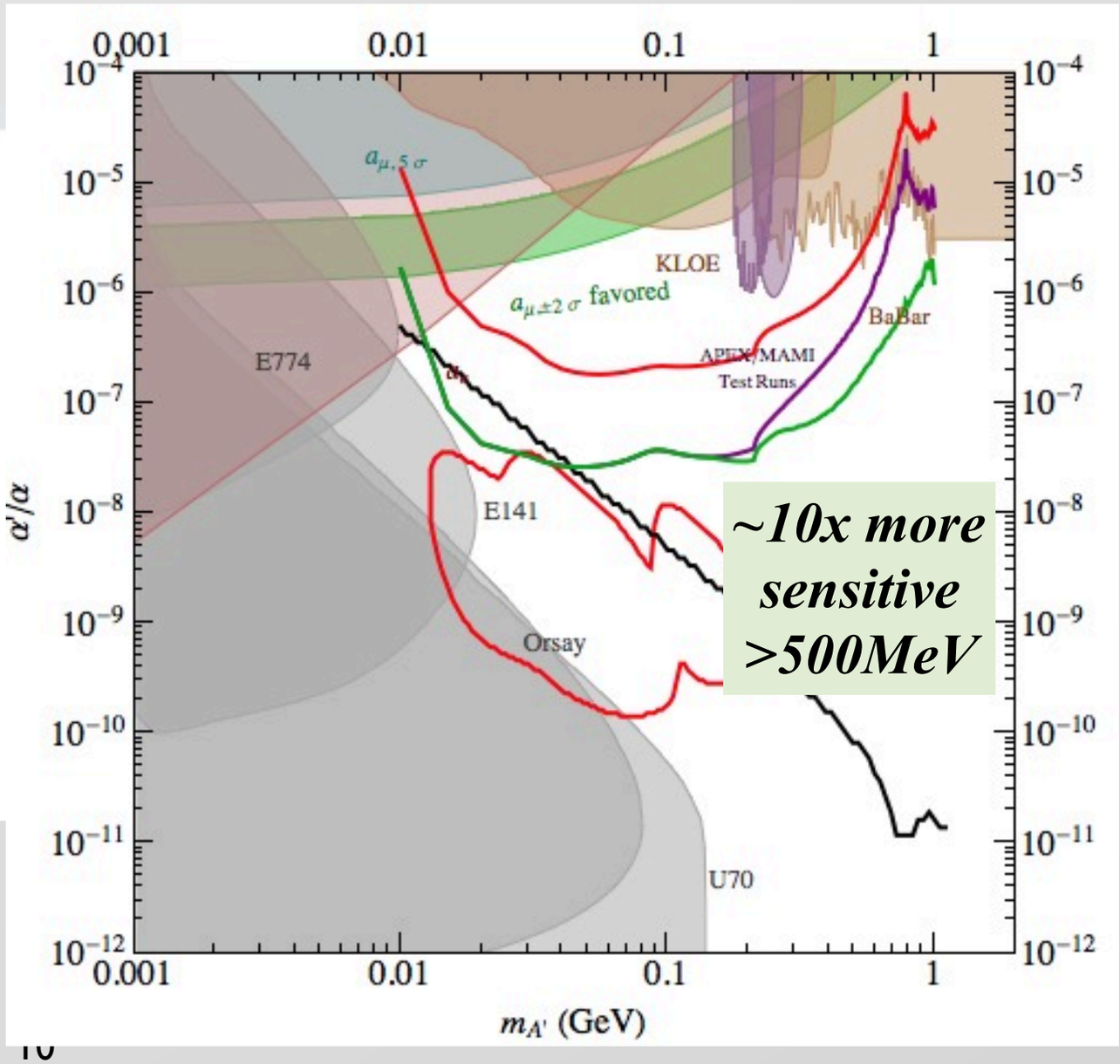




Muons & Pions & 11GeV

- Try to increase reach at mass>500GeV (“Mount Rho”)
  - Add a muon/pion detector to fight loss of branching fraction
  - Run at higher energies: max JLAB will be 11GeV...
  - Lower Z target: next slide (not included in this reach)





High A'Mass→Low Z Target

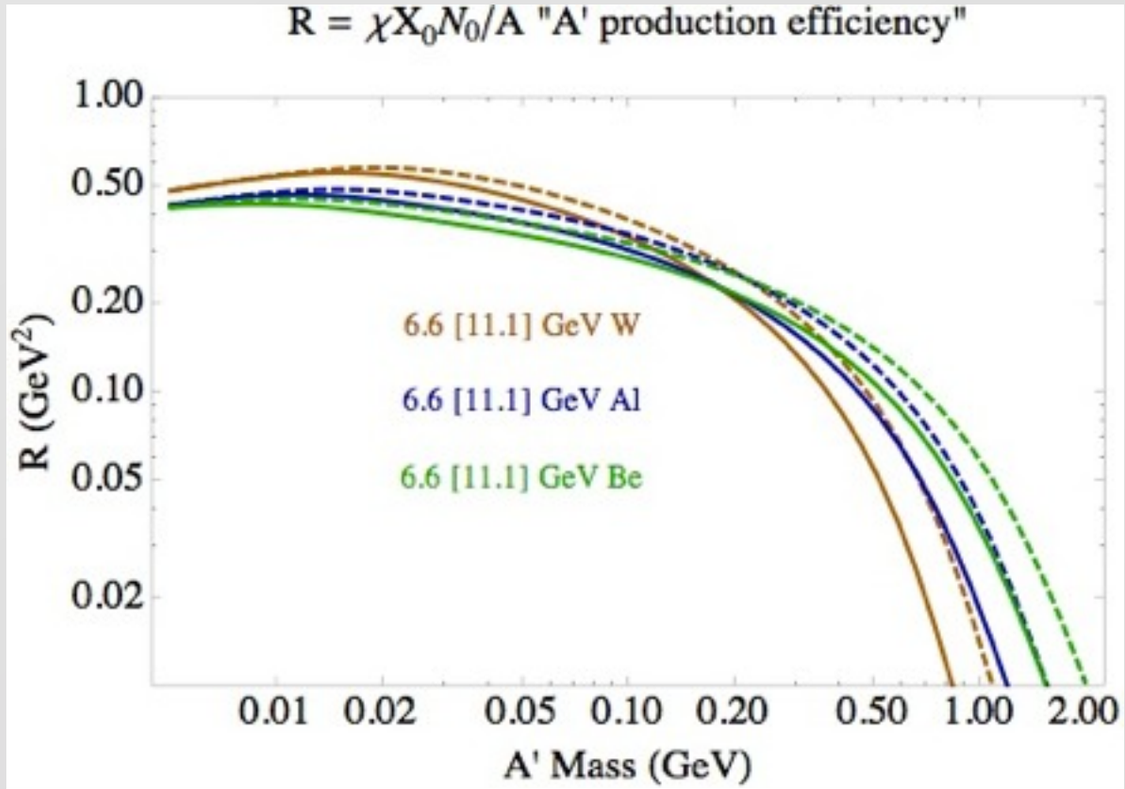
P. Schuster & N. Toro

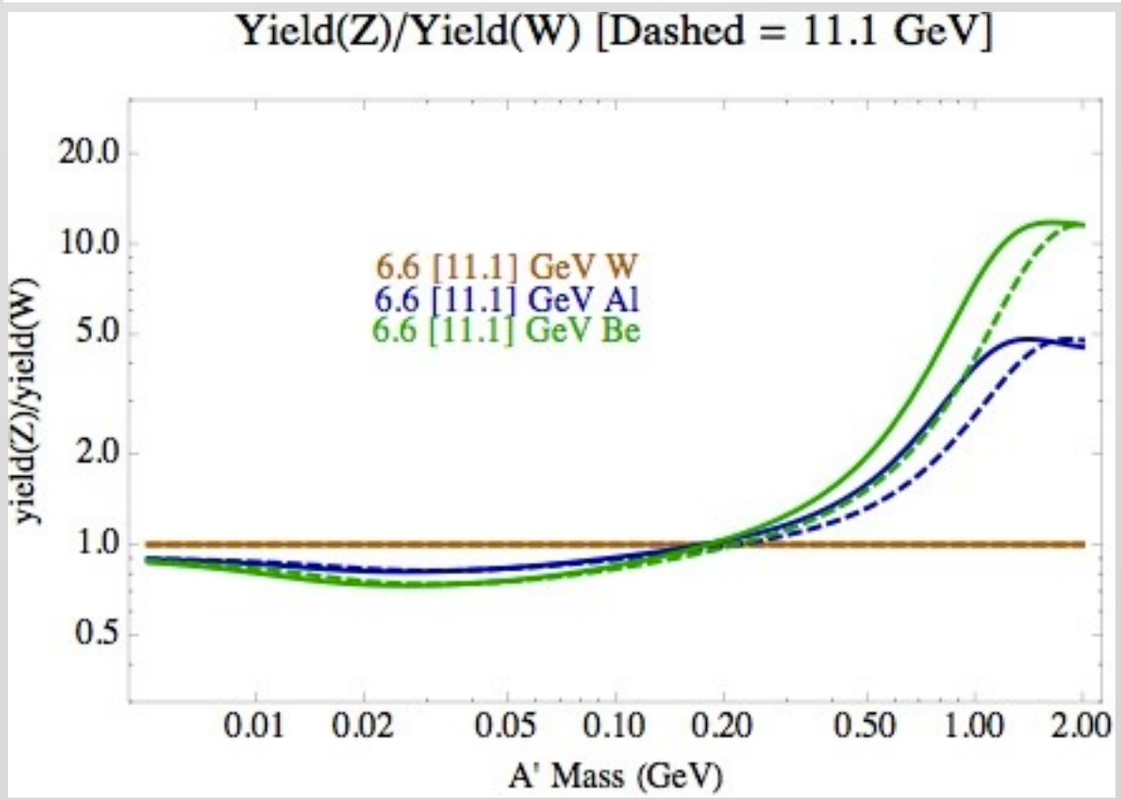
$$\frac{N_{A'}}{N_e T} \sim \frac{X_0 \chi(m_{A'})}{A/N_0} \frac{\alpha^3 \epsilon^2}{m_{A'}^2}$$

"R"

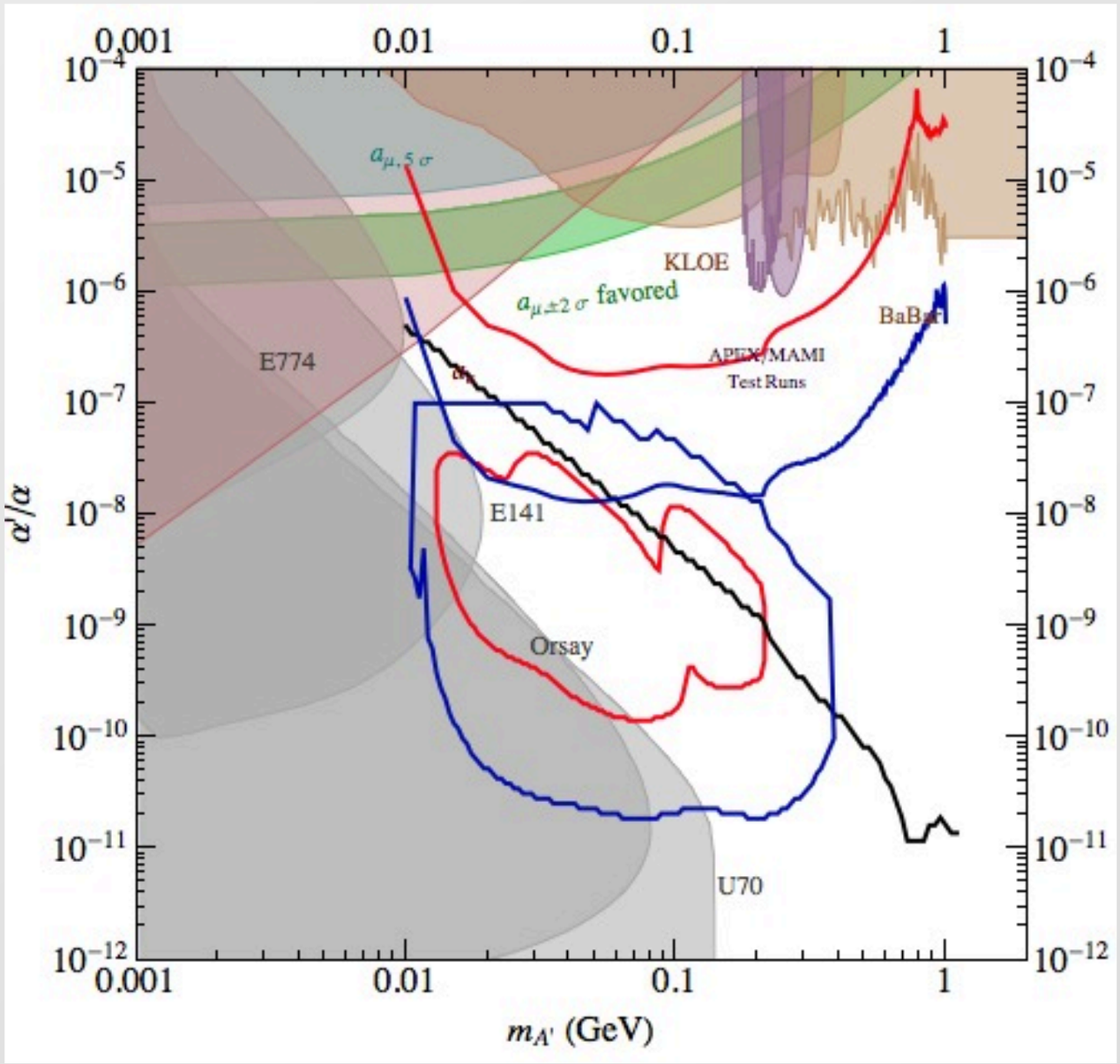
$\chi(m_{A'})$ depends on the nucleus

R dies at higher mass...
BUT it dies more slowly for lighter nuclei...for a Be target, get x10 at 1GeV compared to W
(haven't included this in reach yet, but it's a very good idea!)



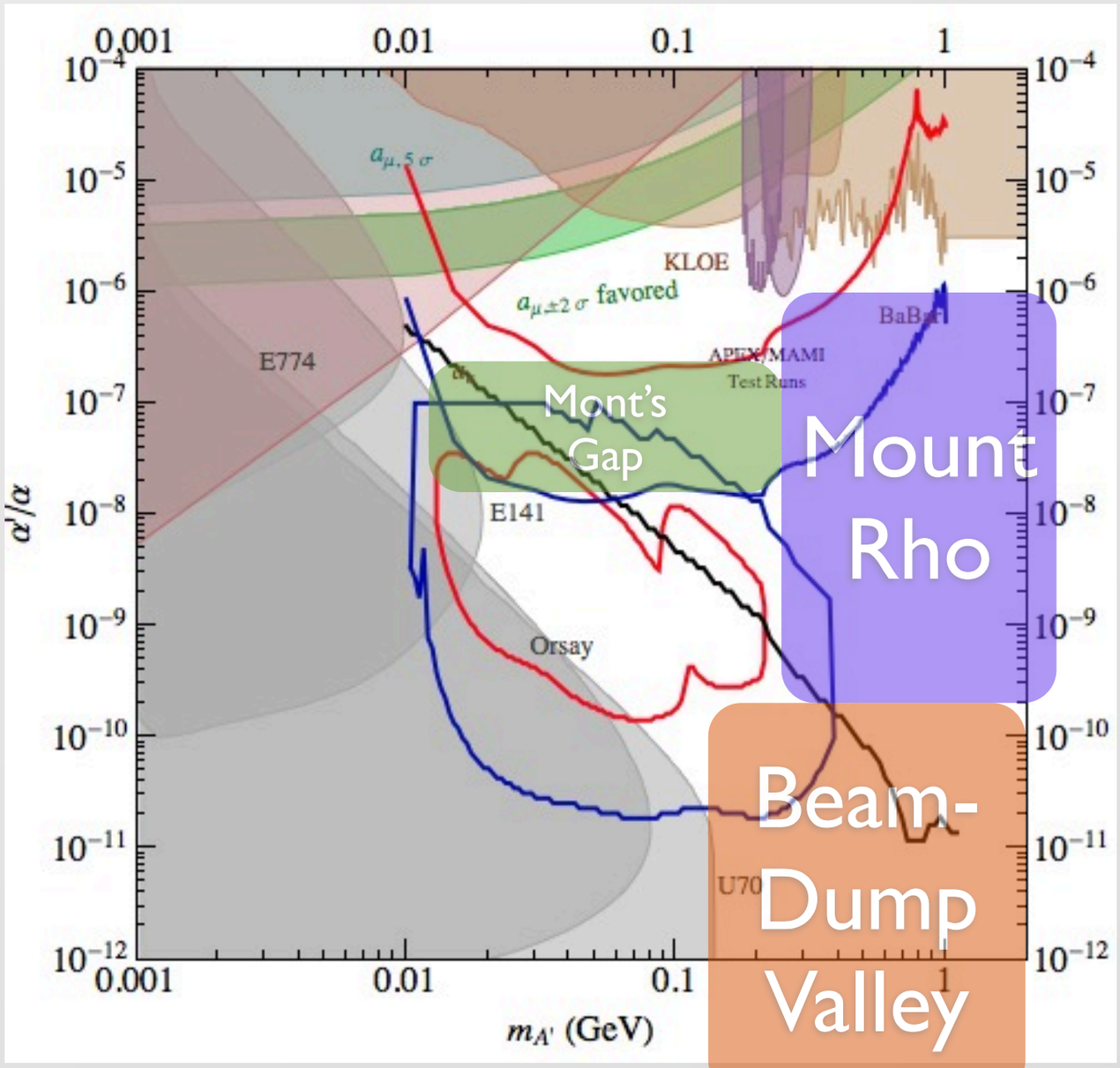


Put it all together: SuperHPS' II



4x mass resolution
2x vertex resolution
60x integrated luminosity

Put it all together: SuperHPS' II



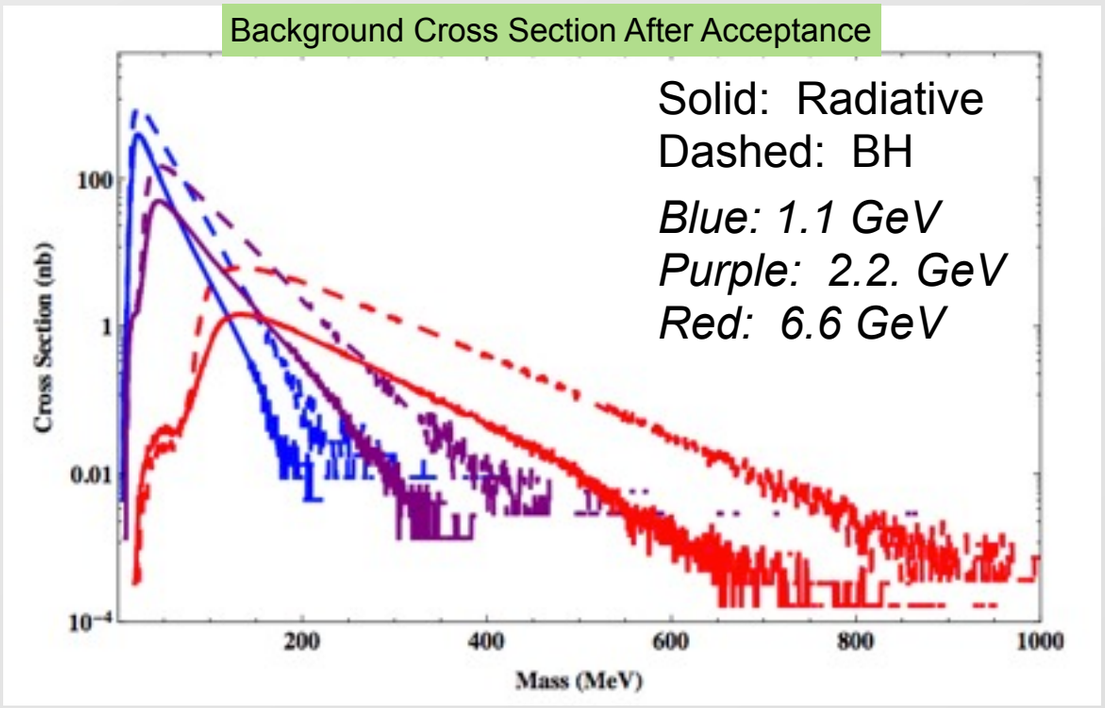
4x mass resolution
2x vertex resolution
30x integrated luminosity
(including 11GeV)

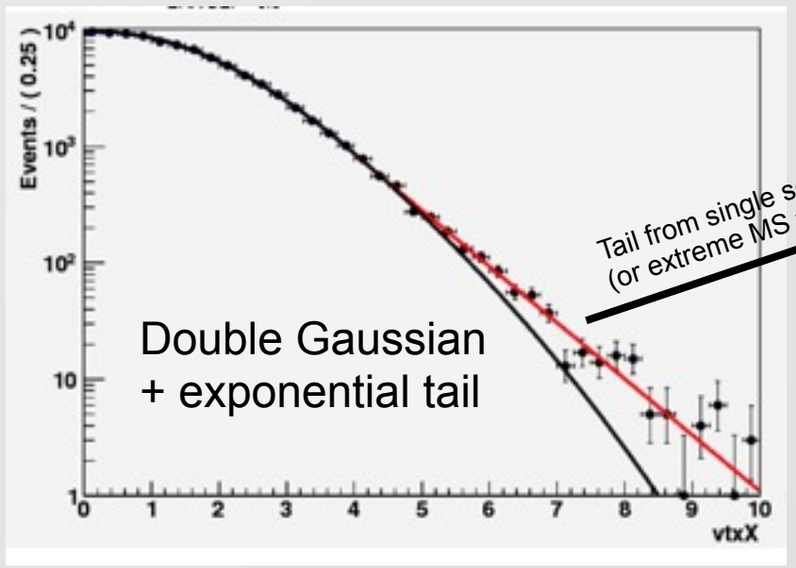
We close ***Mont's Gap***!
Dig into ***Mount Rho***
and lighter targets will help!
Beam-Dump Valley is starting to get covered...high power beam dumps probably the way to go.

Summary

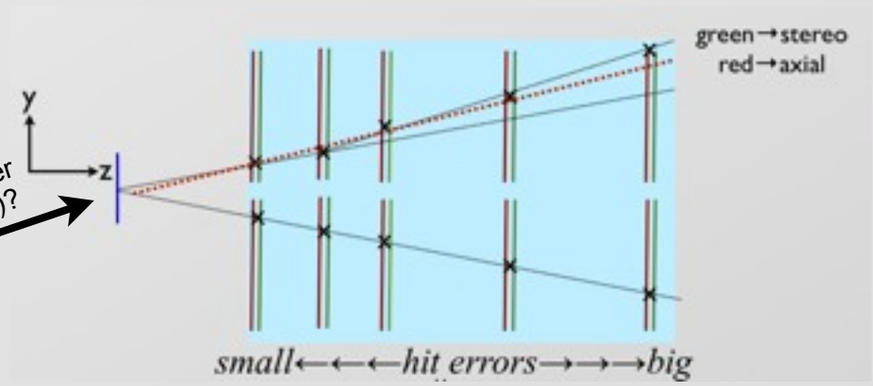
- I've tried to sketch out the territory here...and that's all, just a sketch. Many details and technical challenges would need to be worked out/overcome to see this.
- That said, I don't think it's too crazy...the best thing we can do is run longer (easy, considering nominal HPS has only 6 weeks of beam time allotted right now) and harder (harder, but also probably feasible)
- Mix this with Tim's beam-dump (great for very low coupling & high mass) and double-armed spectrometer ideas (what does this look like for 11GeV?)
- Us fixed target folks never look beyond 1 GeV; left this to the B-Factories. There's a good reason for this: we don't have the beam for it...need CEBAF-24 GeV (or more)!

Background Cross Section After Acceptance





Tail from single scatter
(or extreme MS tails)?



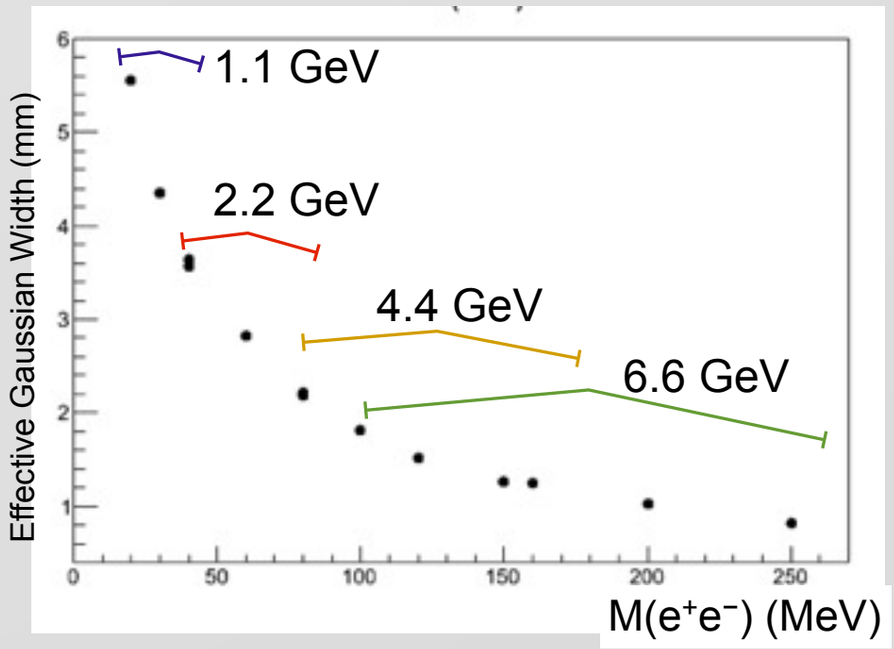
Vertex resolution should be:

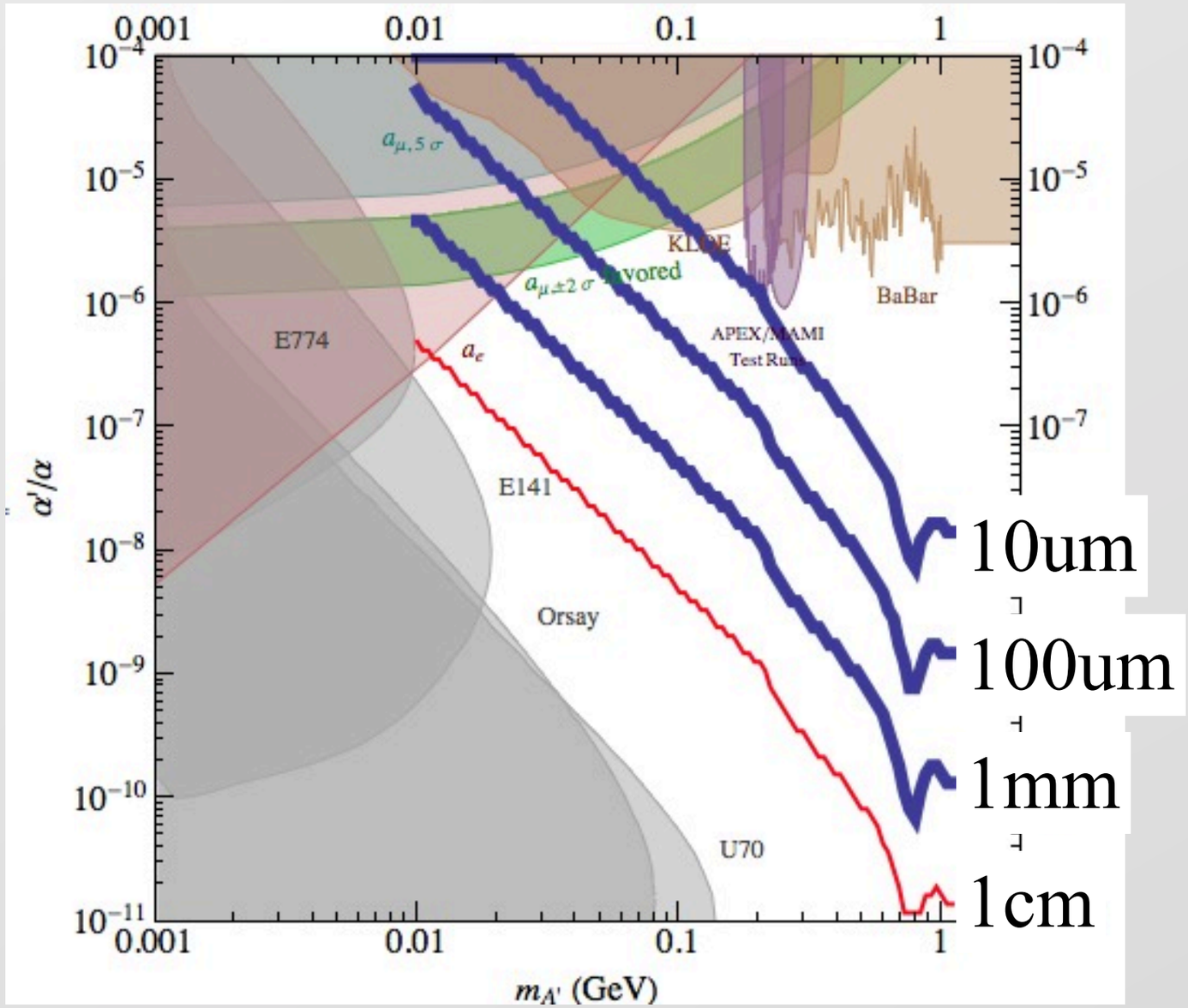
$$\Delta z \sim 2\Delta\theta_{track}/\theta_{open} \times L$$

...so mass/energy scaling should go as:

$$\Delta z(m, E) \sim (1/E) \times (E/m) \sim (1/m)$$

The tail also scales (roughly) with mass.




0.001
0.01
0.1
1
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
α'/α
$a_{\mu,5\sigma}$
$a_{\mu\pm2\sigma}$ favored
a_e
E774
E141
Orsay
U70
KLOE
BaBar
APEX/MAMI
Test Run
10um
100um
1mm
1cm
0.001
0.01
0.1
1
$m_{A'}$ (GeV)